TECHNICAL ARTICLE

Benefits of Xenon Technology for Machine Vision Illumination

In the past several decades lighting systems based on xenon lamps have found their way into many applications. These include camera strobes, analytical instrumentation, anti-collision lighting for aircraft, obstruction warning lights for tall structures, surgical illumination, theatrical lighting, lasers and machine vision. Combining high intensity short pulse width light, a wide spectral distribution, excellent color balance in the visible region, long life and stable spectrum over life, xenon lamps are especially well suited for machine vision applications.

ABC's of Xenon Technology

Xenon lamps come in the form of either continuous-wave (CW) or strobe systems. CW xenon lamps are an excellent choice for machine vision applications where continuous light and a good color balance are required. Xenon strobes, or flashlamps, combine the wide spectrum and color balance of CW xenon lamps with the ability to produce short duration pulses of high intensity light. The remainder of this article will deal with the technology of xenon strobe systems and the associated benefits to machine vision applications.

In its simplest form, a xenon flashlamp is composed of a sealed glass tube with an electrode at each end and filled with xenon gas. Electrical energy is stored in a capacitor connected across the flashlamp, see Figure 1. When the flashlamp is to be flashed a high-voltage pulse is applied to the lamp to ionize the gas. This provides a discharge path for the energy stored in the capacitor. As the current flows through the lamp it is converted into optical energy. Once the energy in the capacitor has been drained, the lamp extinguishes and the capacitor begins to charge again.

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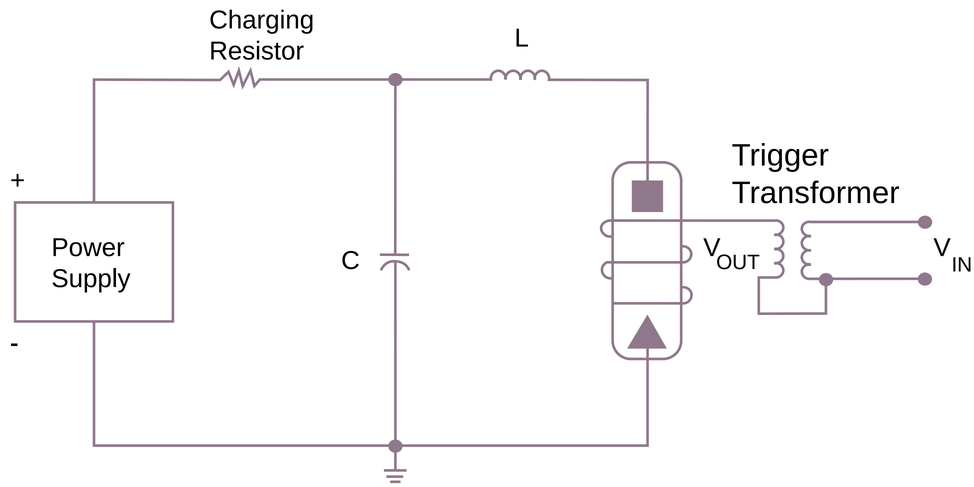

Figure 1. Typical Flashlamp Discharge Circuit

Linear and Short Arc Flashlamps

Flashlamps can be divided into two basic styles, linear flashlamps and short-arc flashlamps. A Linear flashlamp is basically a cylindrical glass tube with electrodes at either end. One of the biggest advantages of linear lamps is the variety of sizes and form factors available. Arc lengths can vary from less than one inch to over six feet. With proper cooling, linear lamps can be run at very high energy and power levels. Linear flashlamps generally produce pulse widths from 30 microseconds to over several milliseconds.

In machine vision applications, linear lamps are typically installed inside reflectors that can either concentrate or distribute light. The choice of lamp and reflector combination can be optimized to illuminate an object from all directions. Using linear lamps in this fashion can often eliminate the need for fiber optic cables. The optical losses inherent in fiber optic bundles are thereby avoided.

Short-arc flashlamps are similar to the linear flashlamps, except that now the arc spacing is typically 1-3mm. Shorter arc spacing allows the lamp to generate shorter pulses of light, typically from 1 to 20 microseconds. A variation on this lamp type is the bulb type flashlamp which can produce flash to flash variations of less than 2%. Short-arc flashlamps are generally used in fiber-optic illumination systems, although direct illumination with these lamps is also an option.

High Intensity Lighting Improves Imaging

Pulsed xenon systems excel at being able to produce high intensity light. Xenon can produce in excess of 250,000 candela, a measure of optical intensity, per flash, and be visible from over 10 miles away. Currently available LED's typically have intensities measured in the tens of candela.

Another example is a 150-watt quartz-tungsten halogen lamp commonly used in fiber-optic illumination. These sources produce around 600 lumens at the end of a half-inch diameter fiber bundle. With a 20-microsecond integration time, this yields 1.2x10-2 lumens per integration period. A 43-watt xenon flashlamp based system running at 20 flashes per second would produce about 9 lumens over this same integration time. Increasing the flash rate to 60Hz for the same 43-watt system would yield about 4 lumens over this 20-microsecond time period.

Increasing the optical intensity allows for superior camera performance, especially in terms of increased depth of field and shorter integration times.

Short Pulse Width Stops Motion and Eliminates Blur

The short pulse width of xenon flashlamps makes them an excellent choice for applications where stop-motion analysis is required, such as for high-speed inspections. A flashlamp can be used to "freeze" a part on a production line as it passes under a camera for inspection. The consistency at which the flashlamp can be triggered is also a major benefit in these applications. Typically the temporal variation from one flash to the next is less than a microsecond. In some situations the pulse of light from the lamp can be used in place of a shutter on the camera. This is especially true for ultra-short, less than 1 microsecond, exposures with film cameras used in ballistic studies.

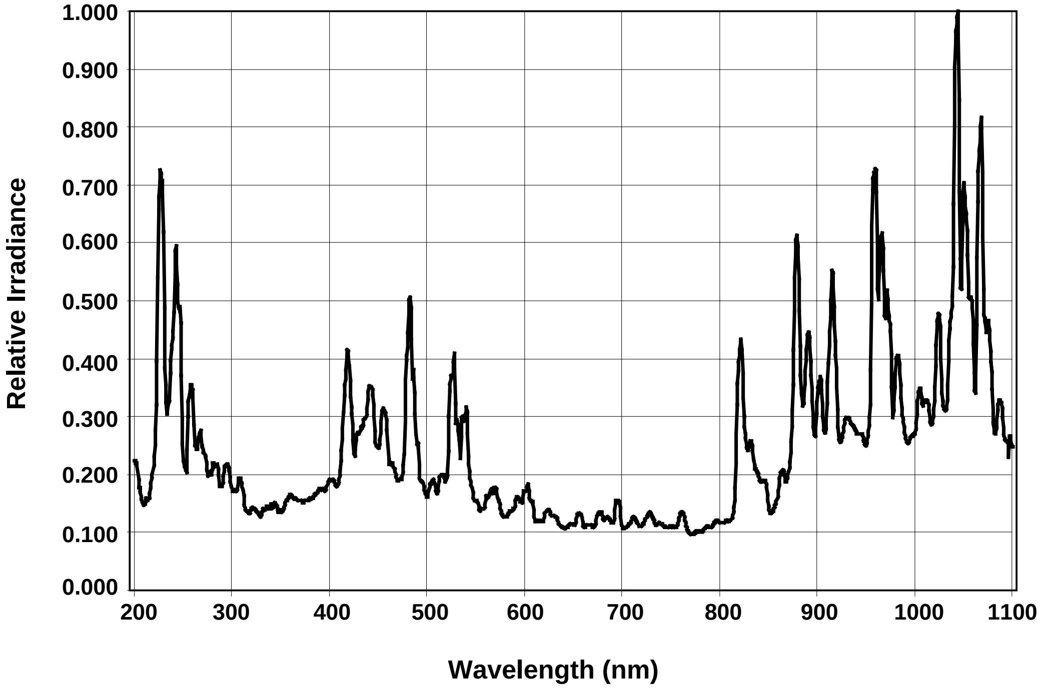

Figure 2. Typical xenon spectral output illustrates wide spectral distribuiton and excellent color balance.

Full Spectrum Light: Accurate Color Rendition

Figure 2 illustrates the typical spectral distribution of xenon flashlamps between 200 and 1100 nm. However, the optical energy released by a xenon lamp covers the spectrum from below 150nm to greater than 6um. Xenon flashlamps provide a good, strong continuum of optical energy in the visible region. The visible region is also relatively flat in terms of spectral distribution. This is especially true when comparing them to tungsten-halogen and LED based lighting systems. Additional color balancing filters are generally not necessary with xenon based lighting systems. The color temperature of pulsed xenon lighting ranges from around 5500K to over 12,000K, depending on operating conditions.

Simple Spectral Filtering for Light Optimization

The wide spectral distribution of xenon flashlamps also makes them ideal for applications requiring light in specific spectral regions. A filter centered on 360nm can be placed in front of the lamp to provide a light source for fluorescence applications, such as checking for coating application as a part passes the inspection station. Alternately, an infrared pass filter can be used when direct viewing of the flash is undesirable, such as automobile traffic monitoring systems. Visible pass only filters can also be employed when "cold" light is necessary. The glass used in the construction of the flashlamp itself can also play a role in spectral filtering. Glass types can be chosen to produce an ozone free lamp or a lamp that does not transmit below 350nm.

Reduces Power Consumption

Flashlamps only produce light when the camera is ready, which has some associated advantages. One advantage is a much lower powered light system for a given application. For example, consider a system inspecting parts at a rate of 20 parts per second. Let's say that 50mJ of optical energy is required at the end of a fiber-optic bundle to adequately illuminate the part and the integration time on the vision system is set at 15 microseconds. A xenon flashlamp system operating at these conditions produces 1 watt of optical power (50mJ x 20 pps). A system based on a continuous lamp would have to produce in excess of 3300 watts of optical power (50mJ/15 microseconds). In this example 99.97% of the time the camera is off, but the power from the continuous lamp is still on. This can lead to thermal problems within the system and a shorter lifetime for both light source and the delivery optics. The above example assumes approximately equivalent spectral distributions.

Available Xenon-Based Machine Vision Illumination Systems

Both short arc and linear lamp types are available in systems designed specifically for machine vision applications, see Figure 3. New generation systems are easy to use, small in size, have longer life and are cost effective. Generally all that is needed from the end user to supply input power to the lighting systems, either AC or DC, and a trigger signal, typically TTL compati-

Figure 3. Xenon Machine Vision Illumination Systems and Lamps

ble. Most of these systems allow the machine vision system designer to vary the voltage across the flashlamp and thereby change the optical intensity of the system. Most xenon strobe systems also allow variable control of the flash-rate, typically up to 200Hz and sometimes up to 1000Hz. The standard short-arc lamp systems accept a wide variety of fiber optic cables including single and bifurcated fiber bundles, ring lights, line lights, and back lights. Some linear lamp systems are so small in size that they are comparable to some fiber optic form factors, yet provide higher amounts of light output than possible through a fiber. These systems are ideally suited for applications requiring extreme amounts of light while keeping the size of the system to a minimum.

Often the packaging of available systems shield the light to address the rare condition of certain people known as photosensitive epilepsy. Only a few percent of the population is photosensitive, generally in the range of 5-30 Hz, according to the National Society for Epilepsy (NSE). NSE cites other triggers for photosensitivity including TV, video games, sunlight through trees, looking out of a window in a train and sunlight on water.

If an off-the-shelf system does not meet the requirements of the lighting application, xenon flashlamps can be built into modular or custom lighting systems. This may be nothing more than providing a longer flashlamp to cover a wider area all the way to a custom enclosure containing multiple flashlamps, reflective optics, and multiple power supplies. A system such as this allows the user to individually control the intensity of each lamp. This type of system provides uniform lighting of non-uniform parts. A modular system may also involve several different types of flashlamps. For example, two linear flashlamp/reflector combinations can be used in the visible light region to inspect the color accuracy of a printed part. Two additional linear lamps with ultraviolet filters could be then used to check for the fluorescence of a coating applied to the material. Finally, a short-arc lamp can be used with a fiber backlight to check for print registration on the part.

For many years, xenon strobe illumination systems have served machine vision system designers with high intensity, short pulse width and wide spectral distribution quality lighting. These attributes help to improve the camera image, increase the camera's depth of field, shorten camera integration times, eliminate the need for a camera shutter, improve color rendition, reduce power consumption and allow for high speed inspection.

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Note: All specifications subject to change without notice.

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